Reply to comment by A. Rapolla on "The Bay of Naples (southern Italy): Constraints on the volcanic structures inferred from a dense seismic survey"

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1. Foreword

[1] *Judenherc and Zollo* [2004] (hereinafter referred to as JZ2004) describe the analysis and three-dimensional (3-D) tomographic inversion of first *P* arrival times from data sets obtained during the controlled-source seismic experiments carried out in 1997 (MAREVES) and 2001 (SERAPIS) in the Neapolitan volcanic bay area.

[2] Thirty years after the 2-D, near-vertical seismic reflection survey of the Neapolitan bay area, made by Osservatorio Geofisico Sperimentale di Trieste (OGS) and whose results are described in the pioneering work of *Finetti and Morelli* [1974], the SERAPIS exploration project provides an unique 3-D, global offset (simultaneous near-vertical and wide-angle data acquisition) data set allowing the investigation of crustal structure in the area with a detail not achievable using previous available data.

[3] As detailed in JZ2004, the dense spatial coverage provided by more then 6000 air gun sources and 150 three-component seismic stations (deployed both on land and at the sea bottom) allowed reconstruction of the high-resolution, three-dimensional image of the shallow crustal structure beneath Campi Flegrei caldera and Bay of Naples down to 6–7 km depth.

[4] The comment by *Rapolla* [2005] (hereinafter referred to as RAP2005) does not bring the results of JZ2004 into question but mainly focuses on the claim that some of the 3-D seismic tomography results could be already known from the existent literature and not referred in JZ2004.

[5] In particular, RAP2005 debates two major points:

[6] 1. JZ2004 shows the existence of the Pozzuoli-Banco di Fuori fault (PBF) fault (a 30 km long, SE-NW normal fault cutting the limestone top at 4–5 km depth), which RAP2005 associates with a NE-SW trending, shallow fault/fracture system previously reported by *Bruno et al.* [2003] and *Bruno* [2004], called the Magnaghi-Sebeto (MS) line.

[7] 2. JZ2004 does not give proper credit to a number of papers (cited in RAP2004) dealing with the geochemical/geological/geophysical investigation of the Campi Flegrei caldera.

2. PBF Fault Versus MS Line

[8] As revealed by 3-D seismic tomography images in JZ2004, the PBF fault runs from the eastern rim of the Campi Flegrei caldera toward the SE for an approximate length of 35–40 km (Figure 1). It appears to be subparallel to another extended fault (TG, Torre del Greco fault), whose existence was already known from the literature. Both these faults affect the 3–4 km and 4–5 km layers with an average scarp height of 1–2 km as it can be inferred from tomographic vertical sections (e.g., Figure 12 in JZ2004). Because of the depth and velocities of formations affected by the vertical fault shift, these tectonic features are interpreted as normal faults that deformed the limestone basement in the context of middle Pleistocene NW-SE extension.

[9] Concerning the seismic evidence for the Magnaghi-Sebeto line (MS), RAP2005 mainly refers to recent articles by *Bruno et al.* [2003] and *Bruno* [2004], which are based on the reprocessing and reinterpretation of 2-D seismic reflection data acquired by OGS in the Bay of Naples during early 1970s [*Finetti and Morelli*, 1974]. According to *Bruno et al.*'s [2003, p. 209] definition the MS line is observed as a "main alignment of NE-SW striking faults and fractures..visible up to Ischia and Procida islands" and also "..Many faults/fractures are segmented and in an en echelon arrangement; some are subvertical, with modest vertical offset and located right below well-known volcanic banks...."

[10] In Figure 1 we have reported the fault/fracture alignments of MS line as inferred from *Bruno et al.* [2003] on the V_P tomographic image for the layer at 3–4 km as from JZ2004. Figure 1 clearly shows the weak spatial correlation between the MS line and the PBF fault which appears as a marked, almost linear, SW-NE lateral discontinuity in the *P* wave velocity field (from about 6 km/s to the SW to about 4 km/s to the NE).

[11] More critical is the comparison between the MS line and PBF fault if we consider the depth resolution of reflection seismic data used by *Bruno et al.* [2003] and *Bruno* [2004]. The numerous seismic sections reported by

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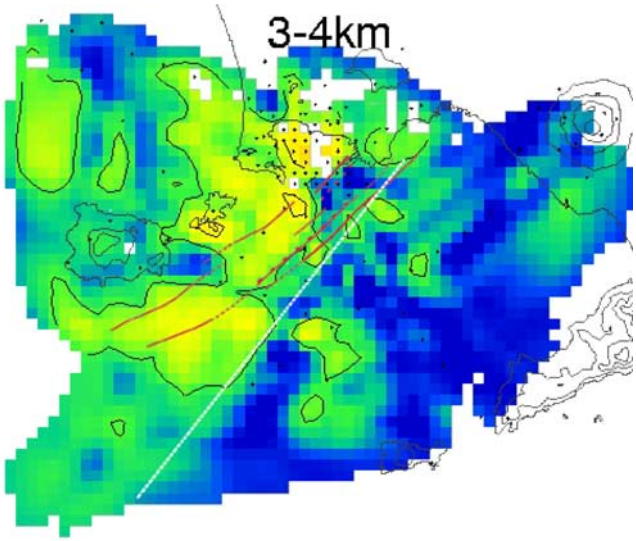

Figure 1. Lateral variations of V_P velocity in the layer 3–4 km as inferred from the 3D travel time tomography of Serapis and Mareves data sets (JZ2004). The alignments of fault/fractures indicated as the Magnaghi-Sebeto line of *Bruno et al.* [2003] are also reported. The PBF fault is clearly visible as a 30–40 km long, SW-NE trending, lateral discontinuity in V_P velocity field (white curve).

Bruno et al. [2003] and *Bruno* [2004] indicate that MS line has been identified as diffraction and/or modest dislocation effects mostly affecting shallow reflector horizons (two-way times smaller than 2 s) (see Figures 3, 4, 8, and 9 of *Bruno et al.* [2003]).

[12] As reported in Figure 2, the two-way travel times of an expected near-vertical reflected arrival from the basement top and bottom sides across the PBF fault should be higher than 2.4–2.7 s. These two-way time (TWT) values are not consistent with the observations of MS line effects on seismic sections presented by *Bruno et al.* [2003] and *Bruno* [2004].

[13] On the basis of both the geometry, depth/lateral extent, scarp height, and involved geological formations we conclude that the Magnaghi-Sebeto and PBF fault are two distinct and unmistakable tectonic features. We therefore disagree with interpretation of RAP2005, which incorrectly gets the two tectonic features mixed up.

3. Reference to Existing Literature and Innovative Results of JZ2004

[14] About the second point of debate we simply remark that the literature on Campi Flegrei caldera and Neapolitan bay area is vast and a selection of the most relevant articles, related to our work, was necessary. It was beyond the scope of our article to provide a comprehensive review of the whole geophysical, geochemical, and geological investigations done in the area.

[15] More specifically concerning previous active seismic investigation in the area, we believe to have given a proper credit to the original work of *Finetti and Morelli* [1974], whose data have been subsequently used by *Bruno et al.* [2003] and *Bruno* [2004]. Previous studies on volcanological and geological models of the Campi Flegrei caldera by M. D'Antonio, G. Orsi, and coauthors are acknowledged and discussed in our article [cf. *Orsi et al.*, 1996; *D'Antonio et al.*, 1999], although seismic tomography does not provide evidence for two nested calderic structures, as was previously proposed by these authors for the Campanian Ignimbrite and Neapolitan Yellow Tuff eruptions.

[16] The results of *Bruno et al.* [1998] on evidences for the TG fault on land based on AGIP seismic data, have been

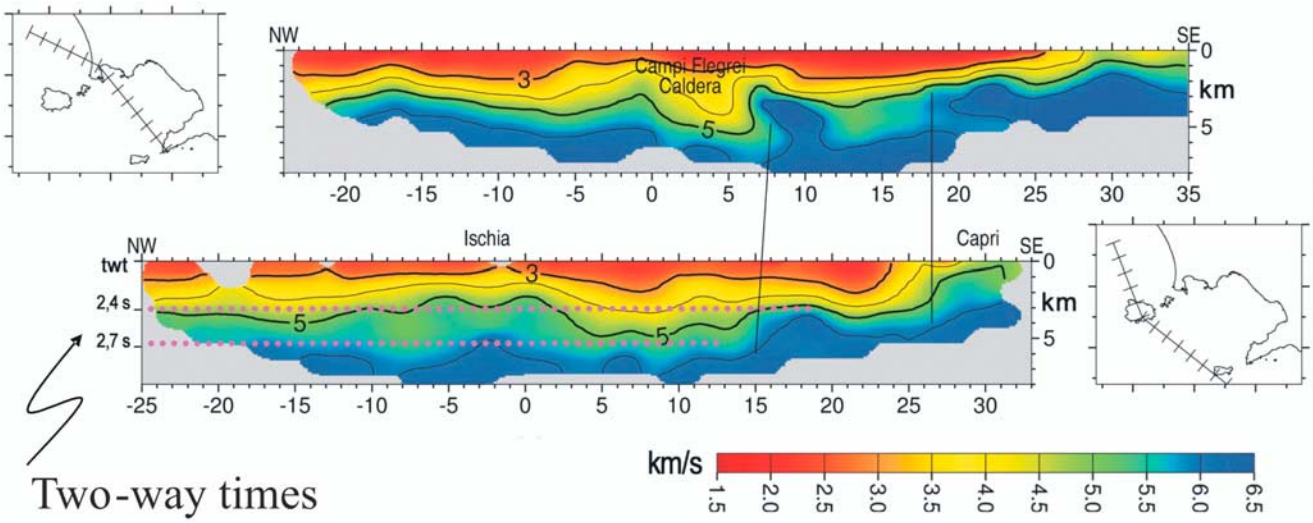

Figure 2. Cross sections in the 3-D tomographic model obtained by inversion of Serapis and Mareves data (no vertical exaggeration)(redrawn from Figure 12 in JZ2004). Small maps show the cross sections, and the tick marks are at 5 km spacings. The two cross sections clearly show the normal faults (PBF and TG) affecting the carbonate platform; their locations are indicated by the thick lines. The two-way times (TWT) expected for a near-vertical reflected arrival from basement top and bottom sides across the PBF fault are reported.

mentioned since they were clearly related to our work. On the other hand, our 3-D seismic tomographic study does not provide evidence for the Magnaghi-Sebeto line [*Bruno et al.*, 2003], probably due to its very shallow extent and small associated dislocations.

[17] As a conclusive remark, we wish to stress that the image of the Campi Flegrei caldera rim, as provided by the joint interpretation of *P* wave arrival times from Serapis experiment, Bouguer gravity and borehole data is an original and innovative achievement of the Serapis project [e.g., *Zollo et al.*, 2003] and not already established from literature as, misleadingly, the final sentences in RAP2005 may lead one to suppose.

[18] None of the previous geophysical investigations (including the papers cited in RAP2005) has shown before the evidence for a single, buried, annular rim of Campi Flegrei caldera as detected by 3-D active seismic tomography at 800–2000 m depth beneath the Pozzuoli bay, with a diameter of about 8–12 km and a height of 1–2 km [*Zollo et al.*, 2003]. While a very high resolution, active seismic exploration made possible such a detailed reconstruction of the caldera structure, it is not surprising that other lower-resolution geophysical observations could not get a similar image definition.

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